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ORIGINAL RESEARCH

DO MALES WITH PATELLOFEMORAL PAIN HAVE POSTEROLATERAL HIP MUSCLE WEAKNESS?

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ABSTRACT

Background: Patellofemoral pain is common in physically active adults. Females with patellofemoral pain have been shown to have posterolateral hip muscle weakness, but there is a paucity of research examining hip muscle strength in males with patellofemoral pain.

***Hypothesis/Purpose*:** The purpose of this study was to examine posterolateral hip muscle strength in males with patellofemoral pain compared to asymptomatic males. It was hypothesized that males with patellofemoral pain would have decreased strength of the hip extensor, hip external rotator, and hip abductor muscles compared to healthy, asymptomatic males.

***Study Design*:** Descriptive, cross-sectional

***Methods*:** Thirty-six adult males with patellofemoral pain and 36 pain-free males participated in the study. The patellofemoral pain group were required to have retropatellar pain reproduced by activities that loaded the patellofemoral joint (squatting, descending stairs, etc.). Peak isometric torque of the hip extensors, hip external rotators, and hip abductors was measured with an instrumented dynamometer. Torque was normalized by body mass and height. Between-group differences were analyzed with parametric or non-parametric tests, as appropriate. The level of significance was adjusted for multiple comparisons.

***Results*:** Hip extensor torque was significantly reduced in the patellofemoral pain group compared to the control group ($p = .0165$). No differences were found between groups for the hip external rotators or hip abductors ($p > .0167$).

***Conclusion*:** Males with patellofemoral pain appear to have weakness of the hip extensors, but unlike females with patellofemoral pain, they do not appear to have weakness of the hip abductors or hip external rotators. The findings of this study suggest that muscle strength factors associated with patellofemoral pain in males may be different from muscle strength factors in females. Clinicians examining and designing plans of care for male patients with patellofemoral pain should consider that the hip abductors and hip external rotators may not be weak in men with this condition.

***Level of evidence*:** Level 3

***Key words*:** Anterior knee pain, hip muscles, male, patellofemoral joint, strength testing

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INTRODUCTION

Patellofemoral pain (PFP) is a common musculoskeletal condition characterized by retropatellar pain during activities loading the patellofemoral joint (PFJ).[1] Typical provocative activities include squatting, ascending or descending stairs, running, and prolonged sitting.[1,2] Onset of pain is usually gradual, occurring with frequent PFJ loading.[3] Patellofemoral pain often becomes chronic and causes significant limitation in sport and daily activities.[3-6]

Physically active adults and adolescents frequently develop PFP,[5,7] with prevalence reported to be 16.5% among runners,[7] 9% of active university students,[8] and 43% of military cadets in basic training.[9] Patellofemoral pain is more prevalent in females than in males,[7,8,10-12] affecting 12% of the general female population aged 18 – 35 years.[13] However, the condition is also common in males with knee pain. Studies have reported prevalence of PFP in males to be 7% of active university students,[8] 16% – 32% of runners,[7,11] and 12% – 38% of military cadets.[9,10] PFP was reported to be the most common musculoskeletal injury in male runners.[7] It is therefore important for clinicians to understand the factors associated with PFP in males.

The etiology of PFP is reported to be multifactorial.[14] One theory proposes that PFP may result from faulty lower extremity (LE) biomechanics, which cause patellar maltracking and increased PFJ stress.[15-19] Excessive hip internal rotation, hip adduction, and knee abduction, causing medial (valgus) collapse of the LE, have been reported in persons with PFP during fast walking, single-leg squat, stepping up and down, and running.[15,20-23] Due to the role of LE muscle strength and function controlling LE biomechanics, researchers have investigated LE muscle function in persons with PFP. A systematic review found strong evidence for hip abductor, hip external rotator, and hip extensor weakness in females with PFP.[24] More recent systematic reviews have found evidence for decreased isometric strength of hip abductors,[25,26] hip external rotators,[25,26] hip extensors,[26] and hip flexors[26] in females with PFP. Weakness of hip muscles is theorized to reduce control of pelvic and hip frontal and transverse plane motion, resulting in LE medial collapse from excessive hip adduction or hip internal rotation.[15,21,27]

Although there is strong evidence for hip muscle weakness as a factor associated with PFP in females, there is conflicting evidence concerning hip muscle strength in males with PFP. A systematic review examining hip muscle weakness in PFP in both genders reported there was only limited evidence that males with PFP had reduced isometric hip abductor strength, reduced eccentric isokinetic hip external rotator strength, and no difference in eccentric isokinetic hip abductor strength compared to control males.[28] This limited evidence for hip muscle weakness in males was based on the results of only one study that included both males and females.[20,28] Additional studies including both males and females with PFP reported less hip abductor isometric strength[29-31] and less eccentric hip abductor torque,[21,32] but no significant difference in hip abductor torque between males with PFP and control males.[21] Mixed-gender studies examining hip external rotator strength have also had conflicting results, with reports of no significant difference between males with PFP and controls for hip external rotator isometric strength[29,30] while another study reported that males with PFP had reduced concentric and eccentric hip external rotator torque.[32] More recently, Bolgla et al.[33] performed a secondary data analysis of baseline data from male participants of a mixed-gender randomized clinical trial (RCT)[34] and found no differences in peak isometric force between males with PFP and control males for the hip abductors, hip external rotators, hip internal rotators, or hip extensors.[33] However, in another secondary data analysis of the same RCT, PFP male responders to hip muscle strengthening were found to have increased hip extensor, hip external rotator, and hip abductor isometric force following the intervention.[35] The authors concluded that some males may have weakness of hip musculature, given the positive response to hip muscle strengthening.[35] In view of the limited and conflicting evidence regarding hip muscle strength in males with PFP, additional studies of hip muscle strength in males with PFP are needed.[28]

The purpose of this study was to examine posterolateral hip muscle strength in males with PFP compared to asymptomatic males, specifically those muscles reported in a systematic review to be weak in females with PFP.[24] We hypothesized that males with PFP would have significantly lower peak isometric muscle torque of the hip abductors, hip external rotators, and hip extensors compared to males without PFP.

METHODS

A descriptive cross-sectional study design was used to examine peak isometric hip muscle torque in two groups of males aged 18–45 years: males with PFP and an asymptomatic male control group. Testing took place in a research laboratory at the University of the Sciences in Philadelphia, Pennsylvania. Study investigators were physical therapists and student physical therapists trained by the lead investigator. The study was approved by the University of the Sciences Institutional Review Board.

Participants

Participants were recruited from the University of the Sciences and the local community via advertisement by flyers, meetings with university athletic teams, referral from local physical therapists, and word of mouth. The inclusion and exclusion criteria were consistent with previous studies.[19,29,36,37] Inclusion criteria for both groups were (1) age 18–45 years; (2) male gender. Additional inclusion criteria for the PFP group were: (1) history of unilateral or bilateral retropatellar pain for ≥ 1 month; (2) the presence of pain with ≥ 3 of the following: prolonged sitting, stair ascent or descent, ascending or descending inclines, running, squatting, kneeling, hopping, jumping, and palpation of the patellar facets or borders. Exclusion criteria for the PFP group were: (1) other musculoskeletal knee or hip conditions that may cause pain or weakness including patellar tendonitis, ligament tears, iliotibial band syndrome, Osgood-Schlatter syndrome, a history of hip or knee joint surgery, hip or knee fracture within the previous two years, acetabular labrum tear; (2) neurological or systemic conditions that may cause weakness or pain such as multiple sclerosis, cerebral palsy, and rheumatoid arthritis. An additional control group inclusion criterion was: no knee pain at time of enrollment or that caused activity limitation for > 2 days in the previous year. Control group exclusion criteria were: (1) all PFP group exclusion criteria; (2) the presence of pain with ≥ 3 of the provocative activities listed as inclusion criteria for the PFP group.

Potential participants were screened for study appropriateness with a questionnaire. Those who initially met all inclusion and exclusion criteria for one of the groups were invited to participate. Written informed consent was obtained and participants' rights were protected during the study.

An a priori sample size calculation was performed for each muscle group using study results for hip muscle isometric force in females with PFP[38,39] using G*Power 3.1.6 statistical software.[40] Required sample size to be sufficiently powered was 20, 48, and 72 participants for the hip external rotators, hip extensors, and hip abductors, respectively (α = .05, power = .80, effect size 1.37, 0.83, and 0.67 [hip external rotators, hip extensors, and hip abductors, respectively]). A sample of 72 participants was planned, based upon the hip abductor muscle test.[39]

Self-reported Symptom Severity, Function, and Activity

Participants completed questionnaires including demographic data, relevant past medical history, medications, and quantification of pain related to the involved knee using an 11 – point numeric pain rating scale (NPRS) where 0 = no pain and 10 = worst pain. The NPRS is a reliable and valid measure of pain intensity that is responsive to change in persons with PFP.[41,42] Participants completed the Lower Extremity Functional Scale (LEFS), a self-report questionnaire of function for persons with LE conditions that is reliable and responsive to change in persons with PFP.[43] The LEFS is scored from 0-80, with 80 = full function.[44] Participants also completed the Tegner Activity Scale, a self-report questionnaire of activity level reported to be valid, reliable, and responsive to change for persons with knee injuries.[45,46] The Tegner Activity Scale is scored from 0–10, with 10 being most active.

Isometric Muscle Torque Testing

Peak isometric muscle torque of the hip abductors, hip extensors, and hip external rotators was measured with a Primus RS™ instrumented dynamometer (BTE Technologies, Inc., Hanover, Maryland, USA). The painful LE of PFP group participants was tested, or the most painful LE in cases of bilateral PFP.[20,47,48] The matched side, right or left, of control group participants was examined.[20] Muscle testing order was randomized with a random number generator. Lever arm length from the dynamometer was recorded for muscle force calculation from peak torque data.

The dynamometer lever arm was locked in place to prevent motion during all tests. Participant test positions for each muscle group were consistent with positions used in previous studies.[20,38,47,49,50] The hip external rotator test was performed with participants seated with the hips and knees at 90° flexion (Figure 1).[38,49,50] The dynamometer resistance pad was positioned with the distal edge just proximal to the medial malleolus. Participants were stabilized with straps around the trunk and over each thigh to maintain hip and trunk positions during testing.[49,50] The hip extensor test was performed with the participants lying prone with both hips in neutral anatomical position (Figure 2).[20,47,50] In an attempt to isolate the gluteus maximus muscle, the knee of the tested LE was flexed to 90° and one investigator monitored maintenance of this position to avoid compensatory LE motion.[51] Straps were used around the trunk and untested LE to maintain neutral trunk and hip position during testing. The resistance pad was positioned against the posterior thigh just proximal to the popliteal fossa. The hip abductor test was performed with the participants in sidelying, tested LE uppermost, with the hip and knee in neutral anatomical position (Figure 3).[20,47,50] The untested LE was placed in approximately 45° hip and knee flexion. Pillows were placed between participants' LE to maintain proper tested LE position. A strap around the trunk was used to maintain neutral trunk position during testing. The resistance pad was placed

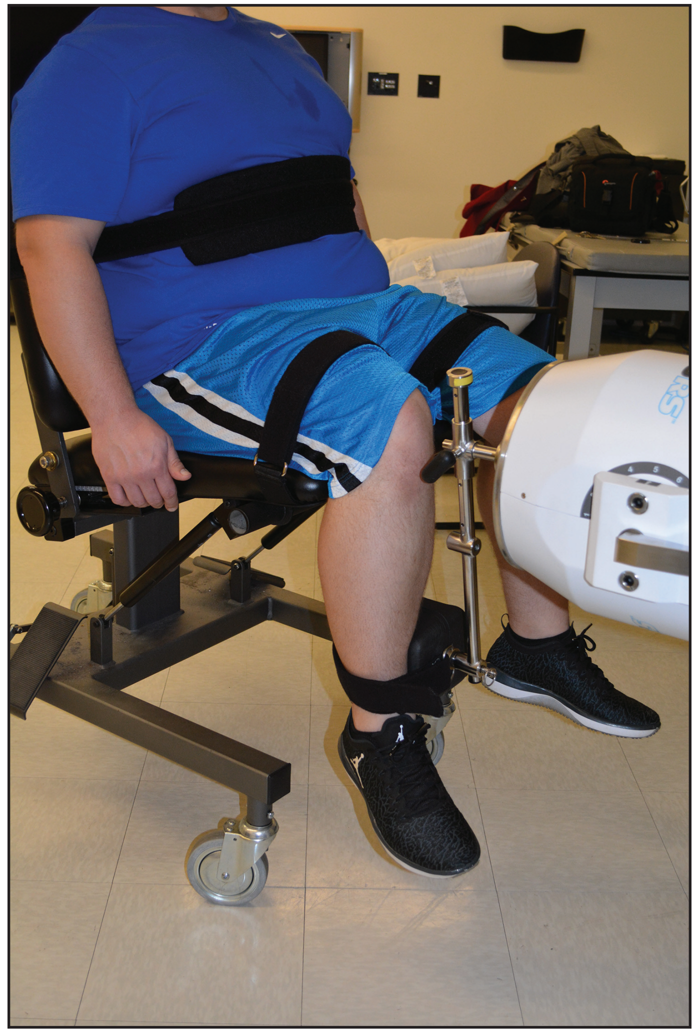

Figure 1. *Hip external rotator muscle isometric torque testing position.*

Figure 2. *Hip extensor muscle isometric torque testing position.*

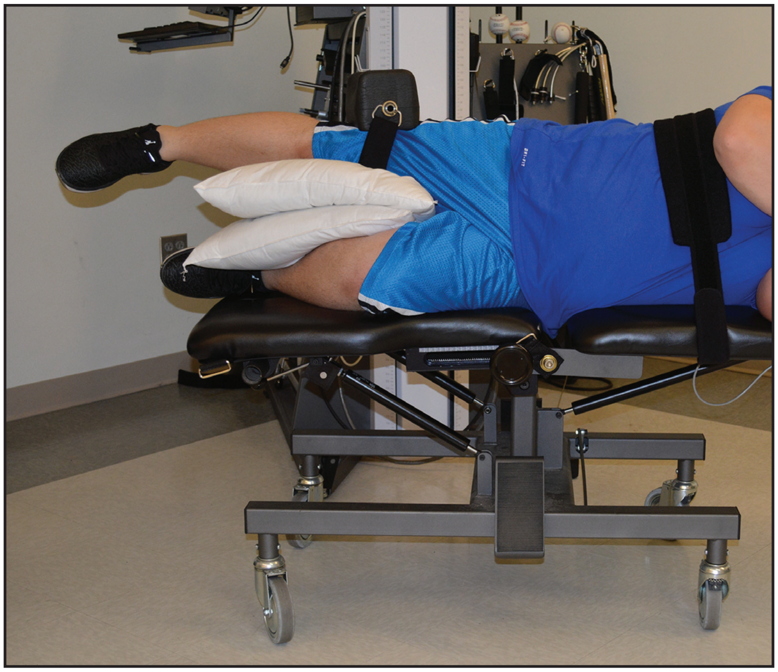

Figure 3. *Hip abductor muscle isometric torque testing position.*

against the lateral thigh with the distal edge just proximal to the femoral lateral epicondyle.

Participants performed three maximal isometric contractions against the dynamometer resistance pad for a duration of five seconds (a "make" test).[47] Participants rested for 30 seconds between trials. Prior to each muscle group test, participants performed two practice trials. Investigators provided verbal encouragement and observed participants during testing to monitor for possible muscle substitutions. Trials in which participants demonstrated compensatory LE motion were deleted and were repeated. If the coefficient of variation of the three trials was > 10%, outlier trials were deleted and repeated.[47,52] The average peak isometric torque of three trials was calculated.[38,47] Average peak torque was normalized by weight and height with the formula {(Newton-meters torque)/[(kilograms body mass)(meters height)]}, as recommended for isometric hip muscle torque.[53] Post hoc analysis was performed to enable comparison of study results to previous studies through calculation of the isometric muscle force expressed as a percentage of body mass. The formula used was [(kilograms muscle force)/(kilograms body mass)].

Test-retest reliability of average peak isometric torque collected with this method was established for both LE for all muscle groups. Five control group participants were tested with the same study procedures on two sessions three to seven days apart. Muscle group testing order was matched between sessions. Intraclass correlation coefficients (2,k) ($ICC_{2,k}$) were used to evaluate reliability and standard error of measurements (SEM) were used to evaluate measurement precision.[54] Results indicated excellent test-retest reliability for all torques as all $ICC_{2,k}$ values were > 0.75[55] (Table 1).

Statistical Analysis

Statistical analysis was conducted with SPSS statistical software, version 24 (IBM Corp., Armonk, New York, USA). Descriptive statistics included means and standard deviations (SD); medians and interquartile ranges were calculated for non-normally distributed data. Data were tested for normality with Shapiro-Wilk tests. Group comparisons for normally distributed variables were examined with independent t-tests, 1-tailed, $p < .05$. Non-normally distributed data were analyzed with Mann-Whitney *U* tests, 1-tailed, $p < .05$. The level of significance was adjusted with a Bonferroni correction for multiple comparisons, with resultant significance level of $p < .0167$. Cohen's *d* effect sizes were calculated using G*Power 3.1.6 statistical software.[40] Effect sizes were interpreted as small (0.20), medium (0.50), and large (0.80).[56]

Table 1. *Isometric muscle torque test-retest reliability and precision: intraclass correlation coefficients and standard error of measurement*

	Left Lower Extremity		Right Lower Extremity	
Muscle Group	**$ICC_{2,k}$***	**SEM†**	**$ICC_{2,k}$***	**SEM†**
Hip abductors	0.963	0.053	0.851	0.078
Hip extensors	0.987	0.030	0.949	0.056
Hip external rotators	0.894	0.033	0.881	0.040

Abbreviations: ICC= intraclass correlation coefficient; SEM= standard error of measurement
*Intraclass correlation coefficient (2,k)
†Standard error of measurement, expressed in Newton-meters of torque.

RESULTS

Seventy-two males participated in the study, 36 in each group. No differences were present between groups for height, mass, body mass index, or physical activity level. The PFP group was slightly older than the control group, had more pain on the NPRS, and had lower function on the LEFS (Table 2).

The PFP group exerted significantly less isometric hip extensor torque compared to the control group. No significant differences between groups were found for isometric torques of the hip abductors and hip external rotators (Table 3). A medium effect size for differences between groups for hip extensor torque was present (Cohen's d = 0.514). Effect

Table 2. *Characteristics of study participants*

Characteristics	Patellofemoral Pain Group*	Control Group*	*p*- Value
Age, median (IQR), y	23.5 (6)	22.0 (5)	.035†
Height, m	1.79 (0.08) [1.76, 1.81]	1.77 (.09) [1.74, 1.80]	.323‡
Weight, median (IQR), kg	79.60 (22.70)	83.53 (20.91)	.656†
Body mass index, median (IQR)	24.88 (3.85)	26.34 (4.15)	.374†
Lower extremity dominance, right / left, No.	33 / 3	32 / 4	NA
Painful lower extremity, unilateral / bilateral, No.	20 / 16	NA	NA
Tested lower extremity, right / left, No.	20 / 16	20 / 16	NA
Numeric pain rating scale score§	4.17 (1.92) [3.52, 4.82]	0 (0) [0, 0]	<.001‡
Lower Extremity Functional Scale score, median (IQR) **	71 (11)	80 (0)	<.001†
Tegner Activity Scale score, median (IQR)††	5.5 (2)	7.0 (2)	.060†

Abbreviations: IQR= interquartile range; No= number; NA= not applicable
*Values are expressed as mean (SD) [95% confidence interval] unless otherwise indicated.
†Mann-Whitney *U* test, 2-tailed
‡Independent *t* test, 2-tailed
§The range for possible scores is 0 to 10, with 10 the worst pain.
**The range for possible scores is 0 to 80, with 80 the best function.
††The range for possible scores is 0 to 10, with 10 the highest activity level.

Table 3. *Group averages for hip muscle torque (body mass and height-normalized) and hip muscle force (percent body weight)*

Variable	Patellofemoral Pain Group*	Control Group*	Mean Difference	95% CI of the Difference	*p*-Value†
Hip muscle torque‡					
Abductors	.658 (.233) [.579, .736]	.703 (.190) [.638, .767]	.045	[-.055, .145]	.1860
External rotators	.350 (.118) [.310, .390]	.396 (.100) [.362, .429]	.045	[-.006, .097]	.0420
Extensors	.411 (.181) [.350, .472]	.512 (.210) [.441, .583]	.101	[.009, .193]	.0165§
Hip muscle force, %BW**					
Abductors	35.91 (12.92) [31.54, 40.29]	38.98 (10.87) [35.31, 42.66]	3.07	[-2.55, 8.68]	.1395
External rotators	18.61 (6.35) [16.46, 20.76]	21.16 (5.19) [19.40, 22.91]	2.55	[-0.18, 5.27]	.0335
Extensors	22.87 (10.10) [19.45, 26.28]	28.44 (11.40) [24.58,32.30]	5.57	[0.51, 10.63]	.0160§

Abbreviations: CI= confidence interval; % BW= percentage of body weight; SD= standard deviation
*Values are expressed as mean (SD) [95% confidence interval].
†Independent *t* test, 1-tailed.
‡Values are Newton-meters of torque/(mass in kilograms)(height in meters).
§Significant difference, $p < .0167$.
**Values are kilograms of force/mass in kilograms.

sizes between groups for hip abductor torque and hip external rotator torque were small (Cohen's d = 0.211 and 0.413, respectively). Post hoc analysis of isometric muscle force expressed as a percentage of body mass had similar results: the PFP group had significantly lower isometric hip extensor force compared to the control group and no differences between groups were present for hip abductor or hip external rotator isometric force (Table 3).

DISCUSSION

The purpose of this study was to determine if males with PFP have weakness of the posterolateral hip muscles. The authors hypothesized that males with PFP would have reduced isometric peak torque of the hip abductors, hip extensors, and hip external rotators compared to asymptomatic control males. The findings partially supported the hypotheses. The PFP group had significantly lower peak isometric hip extensor torque compared to controls, with a medium effect size (Cohen's d = 0.514). No differences were found between groups for hip external rotator and hip abductor peak isometric torques. In addition, the PFP group had significantly greater pain and significantly lower function compared to the control group.

The finding of reduced hip extensor muscle group torque in males with PFP is consistent with systematic reviews of PFP in females, which report strong evidence for weakness of hip extensors associated with PFP.[24,26] But the current findings differ from those of Bolgla et al[33] who did not find significant differences between males with PFP and control males for any hip muscle. The results of the post hoc analysis, a calculation of the force as a percentage of body weight (%BW), enabled us to compare the current study results more directly with earlier studies. Using data from the prior study, the participants' results were lower for hip extensor %BW (Bolgla et al[33], PFP = 28.5, control = 31.3). Both studies examining hip muscle strength in males with PFP tested the hip extensors with the knee flexed to 90°, resulting in primarily gluteus maximus recruitment.[51,57,58] The different findings may be due to varied examination methods of peak isometric muscle force/torque: Bolgla, et al.[33] used a handheld dynamometer (HHD) held against participants by straps anchored to objects while the current study used an instrumented dynamometer. Although research studies have demonstrated that HHD attached to a metal anchoring system is reliable for strength testing of the hip abductors and hip flexors,[59,60] hip extensor strength test results were found to be less reliable.[59] One problem that has been reported during LE strength testing with HHD is "off center" loading of the dynamometer load cell, which may cause inconsistent results.[61] Off center loading may have occurred in the present study as well as in the study by Bolgla, et al.[33] and may be one cause of differing results.

Different exercise participation levels and different pain intensity for participants between studies also may have caused differing results for the hip extensors. Intense levels of physical activity were reported to be associated with greater pain compared to moderate physical activity levels in women with PFP.[62] Hip abductor and hip external rotator strength were not associated with function or pain in persons with PFP; however, no examination of hip extensor strength and function was reported.[63] Inclusion criteria for the study by Bolgla, et al.[33] required males to exercise for a minimum of 30 minutes per day, at least three days per week for the six months immediately prior to study enrollment. In the current study, inclusion criteria did not require a minimum exercise frequency (participants reported a variety of physical activity levels) and there was no minimum pain intensity rating. The greater hip extensor force %BW in the study by Bolgla, et al.[33] compared to the present study may have been due to increased physical activity/exercise frequency by subjects in the earlier study. The study by Bolgla, et al.[33] set a minimum pain intensity rating of 3 cm on a 10 cm visual analog scale (10 cm = worst pain).[33] Increased knee pain in persons with PFP was shown to result in an acute reduction in hip extensor isometric strength.[64] It is unlikely that the differing results between the present study and the study by Bolgla, et al.[33] were due to differences in pain intensity, since the mean (SD) NPRS for the PFP group in our study was 4.17 (1.92), similar to 4 cm on a 10 cm visual analog scale. Thus, participants in the current study as well as the study by Bolgla, et al.[33] appear to have had similar knee pain intensity levels. Although the impact of physical activity on PFP is still unclear,[62,63] differing physical activity levels may have been responsible for different pain intensity[64] and different study results. The current study findings demonstrate that some males with PFP may have associated hip extensor muscle weakness whereas the prior study's findings indicate that in males who exercise at a high frequency, factors other than hip muscle weakness may be involved.[33]

Contrary to the authors' hypothesis, hip abductor and hip external rotator torque were not found to be different between groups. This is different from systematic reviews in females with PFP, which reported strong evidence for weakness of the hip abductors and hip external rotators associated with PFP.[24-26] Our finding of no hip abductor weakness is also different from the findings of the systematic review by Rathleff, et al.[28] However, the current findings are consistent with those of prior studies examining males with PFP.[21,33] This study adds to findings of earlier studies that hip abductor weakness and hip external rotator weakness do not appear to be associated with PFP in males.[21,33] This may indicate that weakness of the hip abductors and hip external rotators are not factors associated with PFP in males, as they are in females.

The findings from the current study add to reports of gluteus maximus weakness in PFP as significantly lower hip extensor torque was found for the PFP group. The testing position for the hip extensors used in this study is reported to primarily recruit the gluteus maximus.[51,57,58] Gluteus maximus weakness may result in excessive hip internal rotation motion and medial collapse of the knee.[50,65] It may be that weakness of the gluteus maximus is the primary hip muscle requiring strengthening in males with PFP. This is consistent with Bolgla, et al.'s[35] findings that male PFP responders to hip muscle strengthening improved most in hip extensor and hip external rotator force and only minimally in hip abductor force. Since hip abductor weakness does not appear to be present in males with PFP, strengthening the hip abductors for males with PFP may not be as critical as it is for females with PFP.[66] Additional research is needed to determine if males with PFP have reduced hip muscle endurance or altered gluteal muscle activation.

This study had some limitations. The PFP group was significantly older than the control group (23.5 [6] y versus 22.0 [5] y, respectively). However, the groups were similar with respect to height, weight, body mass index, and physical activity level. To combine results, torque data was normalized by height and weight, which we believe should minimize differences due to age. The authors did not control for physical activity level or a minimum level of pain as was done in prior studies.[20,21,33] While this may seem a limitation, there was no significant difference due to physical activity between our groups. Therefore, the current study findings may be more generalizable than prior studies, since they apply to males of all physical activity levels. Finally, the power analysis was based on data from females, so the sample size may not have been adequate for males.

CONCLUSION

The results of this study suggest that males with PFP may have hip extensor muscle weakness, specifically weakness of the gluteus maximus muscle. Males with PFP do not appear to have weakness of the hip abductors or hip external rotators. These findings suggest that males with PFP may have different hip muscle impairments than females with PFP.

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